

European International Academic Networking A 20 Year Perspective

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Keywords: Internet, 1984-2004, Research Networks, European Activity

Abstract

The European international academic networking development from a number of isolated research projects into the current powerful unified system is discussed. The repeated interplay between discipline-oriented activities and generic academic computing are considered. The relationship between the European activities and those in other regions – of course including the US, but also other regions of the world is traced. The current initiatives for Europe to remain amongst the world leaders, not only in speed of network but also in helping spread the geographic reach are discussed. Finally, some conclusions and current barriers to full network usage are presented.

Curriculum Vitae

Peter Kirstein is Professor of Computer Communications Systems and Director of Research in the Department of Computer Science, University College London.

Peter Kirstein has been leading research projects in computer communications - mostly in collaboration with European and US colleagues. Amongst these activities are developments in multimedia, active networks, network management, and security applications, and piloting them in the Research Community in Europe and elsewhere. He is currently Director of the NATO and EC-sponsored Silk and SPONGE projects, which are providing a regional satellite based access to the Internet for the NRENs of the Southern Caucasus and Central Asia, and leads the multimedia activities in the EC-sponsored ones on IPv6 deployment (6NET) and security (SEINIT).

Peter was awarded the CBE for Internetwork Research. He is a Fellow of the UK Royal Academy of Engineering, Distinguished Fellow of the British Computer Society, Honorary Foreign Member of the American Academy of Arts and Science, and Fellow of the Institute of Physics, and the Institution of Electrical Engineering. He has written some 200 papers and one book. He has received the Postel award, the SIGCOMM99 and the IEE Informatics Division Senior award for his contributions to the international development of the Internet.

Acknowledgements

This paper has benefited from the comments of many people – particularly Brian Carpenter on the role of CERN. In addition, it has made heavy use of the material available on the web on many details of the many networks mentioned.

1 Introduction

This talk was intended to summarise European Computer network development over the 20 years that the Joint Network Conferences have been held. Thus I start with a summary of the status of the different networks and regions about 20 years ago. 1984 was a time of rapid change, so that some of the developments mentioned as

existing 20 years ago might have come on-line only a few months later; similarly some of the developments stated to be coming up might already have been available.

The early history of these networks, mainly from the US viewpoint, has been presented in many papers e.g. [\[ARPANET\]](#), [\[Internet\]](#). One description as seen from a European viewpoint is given in [\[Kirst\]](#). We summarise, in Section 2, the situation as it was 20 years ago. Here we have to include the US, European National and the connectivity becoming available between the European countries. Of course the networks services available are mentioned also. The timing is important, since the Internet had finally emerged as one of the important set of activities – but there were a number of alternate networks being promoted.

During the first 5-7 years under consideration in this paper, Europe (and North America) were in the middle of the protocol wars. Here there was the party advocating the Internet protocols, those advocating the CCITT protocols of the telecommunications carriers, and those advocating proprietary protocols of specific manufacturers. Section 3 describes something about this war – without going into details of the protocols themselves.

Clearly the global history in this area has been dominated by the USA. Hence in Section 4 we first consider how the US National Research and Education Networks (NRENs) developed, and then trace the European equivalents. This is followed by describing how the connections between Europe and the US developed during the '80s. In the late '80s, the European Commission came onto this scene; we describe their impact, and the significant activity they are now carrying out outside the European Community.

The European scene could not have developed as it has without coordination; the way this grew is the subject of Section 5. There has been a continual dilemma, not only in Europe, on the vexing question of Networks for researchers versus networks for researchers in networks. The US has traditionally provided both; the Europeans less so. The developments here are touched on in Section 6. Finally some conclusions are presented in Section 7.

In a wide-reaching paper of this type, the questions of what reference material to present, or even what exists, is very difficult. Had this paper been written five years ago, the normal format of paper citations would have been essential – though difficult. I have chosen to provide mainly web references. I recognise that there is always a danger that they will not be maintained; however judicious use of web search engines should soon find later equivalents. For this subject, the serendipitous following of links is more illuminating. For the same reason this paper is not full of diagrams and maps. The talk on which the paper is based had plenty of these, and the reference material is full of them. Those who want them should follow the references up themselves.

2 The Status in 1984

The 1984 situation for academic networks was quite different from today. Of course the US was, in most ways, much more advanced than Europe. However in many ways they were more fragmented. Many Europeans were already starting to think that they should have National networks; in the US things were much more focussed on the remits of the different National agencies. Of course this US plethora of activities was often reflected in the European scene – but with subtle differences.

2.1 The US Scene

There were many players. The most significant was clearly the Defence Advanced Research Projects Agency (DARPA). Their mission was clearly to further US defence, but this was interpreted as including the support of Science and Engineering Research – and the infrastructure needed to connect their researchers. The National Science Foundation (NSF) had the basic mission of supporting US academic research in most areas. However the Department of Energy (DoE) had responsibility for High Energy Physics, Fusion and related activities. Also the National Aeronautics and Space Agency (NASA) had responsibility for the space and atmospheric research. These responsibilities have not changed much in the interim – though the relative importance of each for network research and deployment has changed through the years.

In 1984, by far the biggest network for scientific research was the Arpanet [[ARPANET](#)]. It had migrated to the IP Internet protocols a year earlier, and by then had settled down to be stable and important network. Indeed it was stated that there were already 1000 computers networked; most of these must have been part of Arpanet or Milnet. However, being part of the Arpanet was expensive; an Interface Message Processor (IMP) cost about \$90K p.a.; alright if you had DARPA contracts, but otherwise expensive for individual research groups otherwise. In addition DARPA's mission was not to support academic research in general. There was still a strong research arm to DARPA's activities. In fact the Strategic Computing programme [[STRAT](#)] was in full swing, which made heavy use of Arpanet for connecting its researchers. The earlier work on packet speech and packet radio had moved to packet multimedia – fuelled by the needs of Command & Control and distributed simulation. The SATNET packet satellite project [[SATNET](#)], with its European connection, had become a service for UK-US traffic, but the US research had moved to larger domestic programmes. The other SATNET sites in Norway, Germany and Italy had only local traffic (with leased lines to one or two defence installations); they did not have further network connectivity. Specialised networks for research to further the DARPA programme were under discussion, and the transition of the Arpanet technology to a real defence network in the form of Milnet was underway with the Defence Information Systems Agency (DISA).

The NSF had first become interested in networks in alternatives around 1980. It finally had agreed to fund CSNET [[CSNET](#)] in 1981, with the stipulation that it would stop funding it two years later. CSNET provided an interface between IP/Arpanet and other networks – in particular Phonenet and X.25 networks (in particular Telenet). By 1984, the full gamut of mail, file transfer, remote login and name services were available. It had a proper fee structure of \$5K p.a. for university sites, \$10K p.a. for government and non-profit sites, and \$30K for industrial sites. By this time, the initial implementation only on Digital Equipment Corporation (DEC) VAX machines had been broadened to other platforms including IBM. The original CSNET contract included the provision of a gateway to the Arpanet – though its functionality was deliberately limited at the time.

NASA has a remit not only to fund research in aeronautics and space, but also to support its researchers. It has always provided central computing facilities and access to its extensive data files. NASA had set up a networks to meet its needs: by mid 1984, the Space Physics Analysis Network (SPAN) was DECNET based [[DECNET](#)]; a second network the NASA Science Network (NSN) based on TCP/IP was being considered. By mid-1984, this network was US based, but NASA was already considering how to support its foreign researchers.

In the '80s, IBM had a near monopoly of computers for normal academic computing; DEC had much of the research computing, but very few of the mainframes. A project BITNET [[BITNET](#)] was started at City University of New York (CNYU) around 1980,

and by 20 years ago had around 60 computers. Its main facilities were file and mail distribution; these were the functions that main-frames did best. The network was not restricted to universities, and included many of the centres supported by the other US Agencies. Thus the accelerator laboratory SLAC had come on a year earlier and the Fermi National Laboratory in the beginning of 1984. This made it inevitable that there would be pressure for CERN in Geneva to get on also. In fact BITNET was an important marketing tool for IBM. CERN, for example, had gone over completely to Control Data (CDC) computers for its mainframes; the European version of BITNET, called the European Academic Research Network (EARN) [[EARN](#)], was intended to strengthen the role of IBM in academic and research centres. 20 years ago no EARN links existed – but they started coming in very quickly a few weeks later.

The Department of Energy (DoE) supported several operational networks. Their fusion research was supported by some large main-frames, available to their researchers. This had proprietary protocols based on a Livermore-written main-frame time-sharing system called MFEnet. It was, however, providing mainly access to that main-frame cluster. There was also an ESNET [[ESNET](#)] and a HEPNET network based on DECNET, and the connections between the high-energy physics laboratories were based on BITNET.

Finally, there were the mail networks based on either phone lines or leased lines – if the traffic was large enough. Here the main carrier was UUCP [[UUCP](#)] on DEC machines. From the early 1982 there had been a significant deployment of this network – which needed no central management. By 20 years ago the map of the backbone already included “mcvax”, the computer at CWI in Amsterdam. This network service was called UUNET in the US – with its European offshoot called EUNET [[EUNET](#)].

An interesting aspect of the cluster of networks mentioned above is that they obeyed a wide variety of protocols. There were also several large commercial data networks – but these also adopted a variety of protocols. While there was a major standardisation activity amongst the telephone carriers, this had had little impact on the protocols used on the US academic and research networks.

2.2 The European National Network Scene

The European scene was rudimentary. Telecommunications was still a complete monopoly in most countries, which made it very difficult to adopt procedures different from those of the National Carriers. The costs of leased lines were very high, which again made it difficult to go against National PTT policies – since one wanted discounts from the PTTs. The academics had been heavily involved with the development of the OSI standards – in partnership with the PTTs. The very principle of a national network implied shared use of leased lines – which required the agreement of the PTTs.

Very few countries had properly started on National Research and Education networks (NRENs). The UK was a major exception. They had started a network for their research grant-funded activities already in the 70s (SERCNET), and had also put in a considerable number of regional networks to connect to academic mainframes. There had been a report recommending a Joint Network between the two; in April 1984, the Joint Academic Network (JANET) [[JANET](#)] came into service. It was indeed the first such network which connected the facilities both of the main academic computers, and those needed for specific research. This network required close collaboration also with British Telecom (BT), so it necessarily used the X.25 protocol [[X25](#)] at the network level. In fact the British had developed a complete set of protocols covering terminal traffic, transport, LANs, mail, name serving and file transfer. Some, in particular the network level, was part of international standards; the rest were specific to the UK. The UK had also started having experience with US

network, from the gateway to UCL which had already been providing operational traffic for over 10 years (cf. Section 2.3). In addition, JANET provided gateways to the commercial BT packet services and to the EUNET mentioned in Section 2.1.

The two other countries with genuine NREN activity were Norway and Sweden. Both had such networks in place, but were not prescriptive in what protocols they used. Thus while they supported X.25-based networks, they were quite happy to see other network technologies flourish also. Thus, for example, the KOM system from KTH [\[KOM\]](#), Stockholm was installed both in Stockholm and Oslo. The Netherlands also had started their NREN.

The other European countries had networking activities, but few had a real NREN – even in planning. Germany was an exception; they started planning a Deutsche Forschungsnetz (DFN) [\[DFN\]](#) in the early '80s, and the official organisation was founded in April 1984. Its first network went live a little later. However there had also been a project in Karlsruhe U to build a CSNET node; this was ready just about 20 years ago. The question of whether everything should be connected together was still a problem – partly because much of the educational funding in Germany is by Lander rather than national. This is reflected in the name of the German Research Network.

France had several research networks. This was partly because of the rivalry between the research funding organisation (CNRS), the Informatics organisation (INRIA) and the university administrations. INRIA had developed the switches for the CIGALE network, and these had even been used for Euronet (cf. Section 2.3). However by this time it linked only around six laboratories, and was not envisaged as an NREN. There may have been other national networks in being; if so I have not found record of them.

2.3 The European Scene

There had been a number of research projects already in the '70s – partially as a response to the US Arpanet initiative. The European Informatics Network was operational already in the mid-70s – but linked only a single centre in each of France, Germany, Italy, Switzerland and the UK. The centres connected were informatics centres, not universities; usage was not a relevant part of their remit. The data network technology was then used for Euronet, the first attempt at a pan-European network – principally for information retrieval.

There was discussion already then of the need for a European data network to as a service for the collaborative projects funded by the European Commission – but nothing had really started happening (and would not for many more years).

There was a major IBM initiative to build on the success of BITNET in the US to establish a European equivalent called EARN. IBM gave very large discounts to specific institutions which might be the National entry point for an EARN node – but none had actually become operational.

There had been several data network research projects based on satellites from the late '70s. The SATNET [\[SATNET\]](#) one had linked sites in Germany (DFVLR), Norway (Kjeller), Italy (Pisa), the UK (UCL and RSRE) and the US (via Comsat). This was being used for some regular traffic between Arpanet and European sites – but only the UK had really connected in their NREN - JANET. The Norwegians and Italians had connected in their local sites, but the Germans were not permitted to have any real traffic. There were also X.25 links connecting in the SATNET sites to the SATNET control centre in BBN, Cambridge, USA. Another satellite-based network called STELLA involved the Rutherford Laboratory (RAL, UK), Pisa (Italy), Graz (Austria) and CERN. This was used for file transfer between Pisa, RAL and CERN – but was not accessible from JANET, for example.

The British had good gateways to Arpanet (run by UCL) and EUNET (run by Kent U) to their JANET – their NREN. There was also access to the UCL node from PSS – the UK National data network. The link of the UCL IP-JANET gateway to the US was both via the Satellite Network connection of SATNET – which had come out of a DARPA research project in the '70s and the international BT data network IPSS.

CERN in Geneva has always been a difficult, but exciting, location for many branches of science – including networks. Because so many national high energy physics (HEP) research groups worked at CERN, it had to support the extensions of any of their networks. In addition, it had strong networking activities itself – usually incompatible with anything else. The variety of its activities can be seen by the fact that even at that time it support remote links to various European laboratories, had remote job entry links to/from CERN from/to various European HEP laboratories, was on Usenet, STELLA, was part of a DECnet system between various HEP laboratories and was planning its EARN connection. CERN had an X.25 switch, so it was possible for HEP sites to communicate with each other via CERN.

2.4 Network Services

It is not physical connectivity, but the services that they can offer that really define the state of the art. Here the principal services were terminal, transport, file, remote job entry, mail and name serving. At this time all the networks supported some style of mail, and the mail gateways were well developed. Terminal access was an international standard, and was supported on most of the systems – but not really on the UUCP ones; however terminal gateways between different systems were usually not very good, except for the JANET-Arpanet ones. File Transfer had different flavours, and again file transfer between different styles of system were not too prevalent. Remote Job Entry was well-developed in systems like JANET, CERNET, BITNET and Arpanet, but not on the research computers. Name Serving was done by modifying the routing table in DECnet and Bitnet; it was really needed only in the larger networks. In Arpanet, US the Domain Name System [\[DNS\]](#) was well established. However JANET with their NRS [\[NRS\]](#) had quite a different system. The UK case was similar to the Arpanet one – but was single database and had domains the opposite way to the Arpanet one. This required daily updates of the databases, and algorithmic translation between the addresses – which did not always work well. Transport protocols will be considered below.

3 The Protocol War

The '80s was the time of fierce battles between the Internet protocols and the rest. The victories were gradual, and some did not even realise when the war was lost. The PTT networks were particularly concerned with terminal access and network access. For this reason, both network access (X.25) and terminal access (XXX) became CCITT standards very early. Another two standards recognised as vital by the PTT community were mail (X.400) and Directories (X.500). These again had been standardised by 1984, even though there were further changes throughout the next decade. Because these had been embraced by the PTTs and were official policy, It was difficult for the NRENs, as they developed in the next few years, to adopt different standards. Initially both X.400 and X.500 mandated certain transport and network standards; these were therefore adopted also by most of the NRENs to the extent that there was a National policy.

The mail networks like Usenet and EUNET relied on the prevalence of Unix machines containing mail software based on TCP/IP, so they were already using this. DECnet and BITNET had there own protocol suites. CSNET adopted the Arpanet ones by design. In addition many other suppliers, e.g. Apollo and ICL, had yet

different suites. During the '80s, the European NREN providers tried to bring order to this chaos – helped of course by their governments. Most of them insisted that any computers bought for research and education supported X.25, XXX, X.400 and X.500. Several US suppliers fought against this in the beginning; however since the US government had similar concerns, they normally provided these as options.

Of course it was vital to have interoperability of network services, if a global service was to be provided. This was achieved in many ways. First mail gateways were provided; there were many projects which developed these at the same time as the networks. Thus they were provided for in the first CSNET project proposal. UCL, There was still a serious question at which levels these gateways would be provided. Thus, for example, while X.400 and X.500 originally mandated the OSI TP4/X.25 as the transport and network levels below, UCL and others soon also put X.400 and X.500 over TCP/IP. This allowed some of the gateways to be only at the application level, and also encouraged communities to adopt them when their networks had already migrated to TCP/IP.

Financial savings on physical links were particularly important during this period. For this reason X.25 was often used at the network level, with different higher level protocols flowing over the links simultaneously. Thus Italy ran, for example, a National X.25 infrastructure for its NREN in the late '80s, which supported DECnet, EARN and TCP/IP protocols simultaneously. This so-called “multi-protocol” network was used in several NRENs during the late '80s and early '90s.

Local Area Networks were well-established by 1984 – and their protocol war was largely over. In the late '70s and early '80s there were many competing LAN standards: Ethernet, Apollo Domains, IBM Token Rings, Cambridge Rings and Xerox XNS are only some of the variants. Initially they had protocol stacks at least up to the transport level. Fairly quickly these all started to support TCP/IP, and then all except Ethernet gave up the fight. Segal describes the CERN scene, as an example [\[CERN\]](#). They were supporting Symbolics machines with Chaosnet and XNS, Apollo Domains, Cambridge Rings, IBM Token Rings and Ethernet. They put through an agreement in 1985 that TCP/IP could be used internally – but not to the outside world until 1989.

Order came gradually to the protocol jungle. USENET started putting its services over TCP/IP. IBM introduced TCP/IP into the machines being used for BITNET/EARN and DEC into DECnet. Similarly, one started putting X.400 and X.500 over TCP/IP, so that it became possible to run larger scale directory and mail services without protocol translation at the higher levels. As that started happening, it was possible to rationalise the underlying network. It remained only to ensure that IP/X.25 became standard for the lower level network technology to cease being an issue. By the early '90s a common network was achieved, and then the Internet protocols won the whole war – only X.400 and X.500 existing in some places.

At the network level, X.25 remained the European norm, until it was replaced by ATM. ATM again allowed different protocols on top. However, by then TCP/IP had won the war against TP4. When the Web came, HTTP only worked above TCP/IP, there could not be any contest.

As long as there were only a few hundred computers in a network, it was possible to regularly modify the routing tables; this was the procedures used in Bitnet/EARN, DECnet and many of the X.25 networks. The UK had a more complete scheme based on its Network Registration Scheme (NRS). None of these scaled, however; hence as the number of computers increased, the advantages of the Domain Name System (DNS) became clear – and helped win the TCP/IP war.

4 The consolidation of the Networks

4.1 The US Scene

I would have liked to deal exclusively with the European scene. However it is so dependent on the US activities, that this would be impractical.

In Section 2.1 we have already mentioned the activities of NSF in starting CSNET. From the beginning this was envisaged as a finite period project, but its transport protocols were deliberately the same TCP/IP as the Arpanet. In late 1984, NSF launched a supercomputing programme, designed to make these machines available broadly to researchers around the country. They were sited at Purdue, Princeton, San Diego, Urbana and Cornell. Originally NSFNET only connected the five computer centres, but the NSF decided to provide access to all academic users. This was much too broad a remit for DARPA, so that a corollary of the programme was the need for a National network to access these machines. Incidentally an Irishman, Dennis Jennings, was brought in to run the programme. Within a year the flow of traffic was so great that the network had to be upgraded. The subsequent history is well-recorded [[NSFNET](#)]. The decision was made to award the network to Merit Network Inc, a consortium of Michigan universities, the state of Michigan, IBM and MCI. They instituted a multi-tier system, in which they fully funded the National backbone, and partially funded regionally networks in areas that were unsustainable commercially. Although initially only run at 1.5 Mbps, by 1991 it had been upgraded to 34 Mbps. The whole network was, of course, run as an IP network.

With this powerful backbone and regional network in place, there was huge pressure for all the other networks of Section 2.1 to either die out completely, or to transition to run over TCP/IP. While there was some initial resistance, this eventually happened to BITNET, but not for some years; eventually this became standard and IBM even promoted it in the form of Easinet. Both DoE and NASA made some, but not all, of their networks operate over IP. Thus there was a technical capability of moving to all-IP networks. It was only not so essential for ESNET and NASA, because they were operating their own networks for their researchers (even those in universities), and were quite prepared to run separate links. During 1989, both Arpanet (and SATNET) were decommissioned. Those DARPA researchers who merely needed network access obtained it via NSFNET. For the development of more special facilities, DARPA built a series of special networks – DARTNET, the Gigabit Project, CAIRNS etc. Actually all DARPA contractors had a right to use these networks if they had access.

With so many of the networks adopting the IP protocol, it became feasible to consider linking them together. Mail gateways were the most essential, and these had been built already in the mid'80s; they allowed at least mail to pass between the systems. Several of the other networks, like Usenet and Bitnet/EARN, also constructed mail gateways. By the late '80s, the Federal Government had indeed decided to make their main networks able to interconnect this meant at least: Arpanet (DARPA), NSFNET (NSF), ESnet (DoE), HEPnet (DoE), Milnet (DoE), NSInet (NASA) and MFEnet (DoE). For this purpose they organised two Federal Internet Exchanges (FIX-East and FIX-West) in 1987. A brief history of this whole cycle is given in [[Internet](#)]

4.2 The European Scene

In Section 2 I have given a snapshot of the situation in 1984. In fact this was the beginning of a very exciting, and confusing, period for NRENs in Europe. August 1984 saw the first European EARN node at CSATA, Italy. Within six months, there

were many mainframe nodes in Denmark, France, Germany, Ireland, Israel, Italy, Spain and Switzerland. Normally this took the form of an international gateway being installed, and then a very rapid growth of computers inside the country. Since the EARN protocols were so different from others, such a scenario made the concept of a NREN very difficult to pursue. However, since the Europeans were usually wedded to X.25, and did not want too many separate lines, EARN was soon working above X.25 – as part as a multi-protocol environment. By the late '80s, IBM realised that it was falling behind in its penetration into the high-end academic research market. In the US it had put its computers over TCP/IP as part of its response to the NSFNET Supercomputer initiative; In Europe it initiated the EASINET initiative, where it supplied lines between IBM mainframes in each country, and gave large discounts in key establishments. Of course these machines required a TCP/IP infrastructure.

Around the same time, several other communities in Astronomy, Space Physics and others put in DECnet nodes – again with a need to talk to each other. There were thus large deployments of computers which wanted to be part of a research network infrastructure which was mutually incompatible with other such infrastructures. Different countries took different approaches to this problem.

CERN was always a major player in the research community. The NRENs needed access to CERN for the HEP community. CERNET was incompatible with anyone else, but by the late '80s, CERN was also running DECNET, EARN/EASINET

In France, Germany and Italy for example, there were slightly different attempts to resolve the problem. In France, on the whole the different systems were run by different agencies, and hence some network support was provided either by individual universities or by the CNRS. There was, in any case, a prejudice against TCP/IP at official levels. In Germany, DFN provided a network based on their variants of the PTT protocols, and largely ignored the machines which were incompatible. In Italy, the NREN was mandated to support DECnet, TCP/IP and EARN protocols when it came into being.

In the UK, however, a much stricter regime ruled. The Joint Network Team, who were responsible for JANET, mandated that only machines obeying the British Coloured Book [\[CB\]](#) protocols could be purchased with government money – if they were to be connected to JANET. They forced all the approved suppliers to support the Coloured Book protocols, and paid for the development of all the requisite protocol conversions. They then established official gateways to Eunet (at Kent U), EARN (at RAL) and the Internet (at UCL) – supporting the implementation of the relevant protocol conversion – including mail, terminal, file transfer where relevant. This policy allowed them to operate a strong NREN with little distraction from international events. Of course those running the gateways did have to track the continual changes. As a result there was only one EARN node in the UK, although complete connectivity was maintained. It was possible to introduce TCP/IP inside JANET much later, in the early '90s, without any problems with connectivity. They did have to make some concessions to DECnet on JANET, because there was such a strong DECnet research community in the UK in specific fields. Moreover, some external agencies, in particular NASA supplied DECnet machines to their researchers throughout Europe – but they insisted on managing these systems as part of the NSInet. In some cases this was done via dedicated lines, but in some it used a multi-protocol/x/25 infrastructure.

In most countries the migration of the competing technologies of NSFNET, BITNET/EARN, DECnet and UUCP to TCP/IP made it possible to introduce NRENs based exclusively on IP even before the growth of the web made this essential. In the UK the move away from X.25 was delayed – without any loss of functionality. Native IP on JANET was introduced as a service only in 1992, and the X.25 was turned off only in 1996.

4.3 US-European Interconnection

By the late '80s, the US governments networks had various gateways between them. A variety of discipline-based groups in Europe had ever-deepening links with the US. CERN was starting to have closer links with various US HEP laboratories; these were partly achieved via EARN/EASINET, but partly via dedicated links paid for by DoE. MPI-Garching continued its links with the fusion work with LLL, again co-funded by DoE. NASA supported quite a number of research groups in Europe through its SPAN and later NSInet links. DARPA stopped supporting SATNET only in 1989, and thus its links with Pisa and Kjeller; its UK links were supported until well into the '90s. NSF had co-funded a link to Karlsruhe in Germany and INRIA in France onto NSFNET. The first transmuted into a commercial link by 1989; the second moved from just connecting in INRIA to connecting officially the Renater NREN [\[RENATER\]](#) by the early '90s. This motley collection of links became very expensive to maintain, and did not allow much economy of scale. For this reason two approaches developed. With France, Sweden, CERN and Germany, provided TCP/IP was used, they agreed through bilateral agreements between the US agencies to take full responsibility for a country. Thus DoE cost-shared the links to Germany and CERN, since these were used mainly for HEP and fusion; NSF for those France and Sweden. The British ones were particularly complex. Because of the UCL-DARPA links, and the fact that all Janet-NSFNET and NSInet traffic all were supported via UCL (though this was later moved to ULCC physically), there was cost sharing by UKERNA, MoD, NASA, NSF and DARPA. Upgrading the link when all had to agree to pay their share became a bureaucratic nightmare, and NSF dropped out of this early. The others remained involved to near the end of the '90s. This form of shared funding was possible only because the US had set up Metropolitan area exchanges (MAE-East and MAE-West) which could distribute the traffic from single channels onto the relevant federal agency network.

Another reason that NSF dropped out early from this scene is that they had encouraged their regional networks to go commercial. So had other networks like Usenet (which became UUNET in the US, and migrated to commercial nets in Europe also). Their Karlsruhe partner also became a commercial German ISP. Thus many of the European-US links to NSFNET were actually made via commercial agreements by the regional nets (including MCI, who was eventually running the VBNS in the US). These soon had much greater capacity than any of the academic links – which became services bought from international carriers.

4.4 European Networks and the European Commission

The European Commission started the Framework Programme (with different components in communications (RACE), technology (ESPRIT) and applications (Telematics) around 1983 (in fact the different components had different names and remits at different periods over the last two decades). This funded research and development both in industry and academia. It was to include in each project partners from different countries, so it clearly needed a European data communications infrastructure. As mentioned in Section 2.3, there had been a European information retrieval network, financed by the EC but put in by the PTTs since about 1979. However, by 1984 each of the European PTTs were running their own X.25 networks, with international links to each other and to the US etc; they did not see why anything else was needed. The cost of these switched networks was high, the bandwidth low, and the performance poor; they were both unaffordable and unsuitable for IST purposes. From the beginning it was stated that suitable networks would be provided – but there was uncertainty inside the EC to provide the finance, and hostility by the PTTs to provide such a network.

Eventually, in 1987, the EC funded an X.25 network, mainly based on 64 Kbps lines called IXI; this covered some 18 countries; there was no charge for the international communications, but national access charges for industrial parties could be levied nationally. By 1990, this network was quite inadequate, and a major upgrade was needed – but there was no agreement on what was best; some NRENs wanted X.25, some needed to support DECnet, and some wanted only pure IP community. In 1992 the 2 Mbps European Multi-Protocol Backbone (EPMB) [EMPB](#) was launched; this was multi-protocol, supporting both X.25 and IP, contracted to Telecom NL until 1995, and then by BT to 97. The IP camp decided to set up an organisation, EBONE, and a network with major hubs in London, Montpellier, CERN, Amsterdam and Stockholm – connected with 256-512 Kbps links and three links to the US. The US links were part of the IBM EASINET infrastructure. The network was to be based on multi-protocol upper layers. There were to be a gateway between EBONE and IXI in Holland. Several other countries and networks joined EBONE, including Ireland, Spain, Nordunet, EUNET, EARN. This set of solutions was clearly an interim measure until a more unified approach could be worked out; it was called EUROPANET [EUROPANET](#). When the EUROPANET contract was re-tendered, the PTTs were now often competing, and were not really willing to put up a pan-European network.

The PTTs were all in favour of ATM, and a substantial 2 Mbps ATM infrastructure was proposed. This, the so-called JAMES project [JAMES](#), ran until around 1997. It is important to note that it was part of the RACE programme for developing communications technology.

By 1993, DANTE [DANTE](#) had been established, and the scene set for a pan-European network. Much of the history for the subsequent decade is well reported in the survey given in [EHIST](#). Such a network was launched in 1996 called TEN-34. By then the IP war had been won, and TEN-34 was a pure IP network – involving Western European NRENs, Hungary, the Czech Republic and Hungary. In 1998, it was upgraded to 155 Mbps in the TEN-155 (called QUANTUM) project. These networks had the NRENs connected to them, but they were available for use also by any EC-funded projects; nevertheless, the access costs charged by some PTTs to commercial companies could be quite high – and the EC was not happy to pay somewhat arbitrary charges. By 2000, the link speeds had become much higher – 2.5 Gbps in the GEANT project [GEANT](#), and now, in GEANT-2 they have gone up to 10 Gbps.

In the GEANT projects, novel facilities had become an integral part of the remit of the networks. These included multicast, IPv6, Quality of Service, Virtual Private Networks (VPNs) and detailed measurements. There were some tensions between DANTE, as responsible for the management of the networks, and the researchers on the relative weight to be put on the research. However, in practice the collaboration has worked very well.

Clearly the NRENs had to re-invent themselves several times to keep pace with the JAMES/EBONE/TEN-34/QUANTUM/GEANT transmutations [EHIST](#); in turn those transmutations were necessary to keep pace with the more advanced of the NRENs. The NRENs had different forms in different countries. Thus, for example, SURFNET and Renater kept a strong central homogeneous control of the NRENs. In the UK, there arose a central backbone, and fairly independent regional networks. In Germany [DFN](#) there were both of these, depending on the region in question.

4.5 Foreign Network Connections

The connections to the US have always been different from the rest. We have said much about the early history. Up to the mid '90s, many countries made their independent arrangements. Later these arrangements were ordered for the NRENs,

but the actual provisioning was done by DANTE. Since this would have been difficult for the smaller countries, eventually there were direct links from QUANTUM for these countries. The links have now become very substantial; they are now approaching many Gbps.

From the mid-90s, there have been several other types of international links. Often these started as the initiative of one European country, but then they became general links. Thus there were early direct links to Japan. As a result of a G7 promise made in 2001, a link to the whole Asia-Pacific region via Korea (originally 2 Mbps, but later raised to 34 Mbps) has been put in; there are discussions to put in a second link to Southern Asia. These should encourage the strengthening of the regional NREN links in this area. There are several other such links for different reasons (e.g. to Departments of France in Africa and elsewhere, to China, spurs to Canada for work with CANARIE etc). The EARN links already included Turkey, Cyprus, Israel and various other countries; these remained linked to the European networks as they developed.

Since the early '90s, there have been specific initiatives to the old Soviet sphere of influence. Starting in 1991, the PHARE-1 project [[PHARE](#)], provided Internet extensions from Western Europe to Bulgaria, Czech Republic, Hungary, Poland Romania and the Slovak Republic. During 1994-97, this programme was extended to Albania, Estonia, Latvia, Lithuania and Slovenia. In parallel, under the INSIGHT programme, help was provided to the same countries for extension of the Web.

Already by 1998, TEN-34 included links to all the PHARE countries. It included links also to Ebone, Europanet, Japan (2 Mbps) and the US (9 separate links totalling nearly 400 Mbps). From then on, QUANTUM and GEANT were made to these countries as a matter of course. In addition to these programmes, there have been substantial activities from the Scandinavian countries to bring up the Internet facilities in the Baltic area and Northern Russia.

From 1994, in a completely separate initiative, the Networking Panel of the NATO "Science for Peace" programme, was helping also to establish NRENs in many of the East European countries. In addition their remit included Russia and the Newly Independent States (NIS) of the former Soviet Union, where the grants always included paying for a small amount of Internet connectivity. Their activities were closely linked to others from the HEP community, with particular support from DESY and DFN in Germany, who were funding VSAT-based Internet connectivity to HEP institutes in Russia, Ukraine, Armenia, Georgia and Kazakhstan through a DESY hub. The NATO programme partially funded this initiative, and encouraged these institutes to extend links nationally as broadly as they could. In 2001, the NATO programme was broadened to include the Silk Project [[SILK](#)]. This provides a proper satellite-based VSAT service, again based on a hub in DESY and links into DFN to all the NIS countries of the Southern Caucasus (Armenia, Azerbaijan and Georgia) and Central Asia (Kazakhstan, Kyrgystan, Tajikistan, Turkmenistan and Uzbekistan). That project has substantial input from Cisco, DESY, the EC and the Soros foundation (in order of their contributions), and currently will operate until mid 2005. It provides around 600 Kbps up-link from each country, and a common 15 Mbps downlink; this will increase by around another 50% before the end of the project – partially with funding from other sources.

The European Commission is taking a major initiatives to connect GEANT with other regions.. It has one project [[EUMEDIS](#)] to extend GEANT to the Mediterranean countries – including, Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Malta, Morocco, Palestine, Syria, Tunisia and Turkey. Another connects the South East Europe [[SEEREN](#)]; this includes Albania, Bosnia, Bulgaria, Macedonia and Serbia/Montenegro. They have financed links to S. America [[ALICE](#)], and are discussing a further Asian link – probably to Kuala Lumpur. Finally, there are major

EC, Soros, UNDP and World Bank development projects in the countries served by the Silk countries. There are strong signs that they will also be putting money into strengthening and continuing the Silk Project.

5 European Network Coordination

20 years ago, the European network co-ordination was very limited. Of course the discipline-oriented networks like CERNET, HEPNET, SPAN and SATNET all had co-ordinating bodies, but most of these operated only inside their own discipline. The International Collaboration Board (ICB) [[ICB](#)] had been set up at the same time as the Internet Activities Board (IAB) [[IAB](#)]. The IAB co-ordinated all Internet technology advances, and was initially only US. The ICB coordinated both non-classified international research collaborations between various European and North American defence groups, and also was the steering group for SATNET; its US member was DARPA. There had been a meeting in 1983, during an ICB session, with NSF staff; this was the first time that a set of Europeans from different networking countries met with NSF. The NRENs mainly operated nationally. This showed a need for such meetings – both on a European and international basis.

In 1986, RARE (Réseaux Associés pour la Recherche Européenne) [[RARE](#)] was created with support from the European Commission (EC) in order to provide a forum where issues of common interest could be discussed and ways of linking the existing national services could be worked out. Countries which did not already have a national research networking organisation were also encouraged to create one. Amongst other things, RARE ran various Workshops, and ran a project called Cooperation for Open Systems Interconnection Networking in Europe (COSINE). It was COSINE which funded the IXI network, and a number of initiatives in X.400, X.500 and related subjects. By 1990, it was clear that further co-ordination was needed. The first step was to have the first Joint workshop between RARE and EARN in Killarney.

By 1989, it was clear that IP networking needed co-ordinating in its own right. RARE, with its emphasis on OSI, was not really appropriate. Instead Reseaux IP Europeens (RIPE) [[RIPE](#)] was formed to provide the necessary administrative and technical coordination to allow the operation and expansion of a pan-European IP network.

By 1993, it was clear that two further organisations were needed. First, RARE and EARN needed to be combined. The result was the Trans European Research and Education Networking Association (TERENA) [[TERENA](#)]. The second was that European-wide backbone networks were going to be procured; for this reason, DANTE (Delivery of Advanced Network Technology to Europe) [[DANTE](#)] was set up. Both organisations are essentially owned by the NRENs.

6 Networks for Research versus Research on Networks

Ever since the start of networks, there has been a tension and interplay between research on networks and networking research. For most of the time, the research on networks has been carried out under different auspices from the provision of networks for researchers. Thus while the original Arpanet, Internet and SATNET activities were research and development (R&D), within a few years they had become networks to service researchers. However even after the networks have become service networks, there is still often a need to do further R&D to improve performance and extend functionality. This R&D often needs a real network – but the funds to provide it are often very limited, and the use of the service networks often resisted by their operators.

Most of the work described in this paper has concerned research networks. To bring them into being has required a lot of R&D – most of which has been done under National auspices. For example both the British Science Research Council and the provider of research networks funded much work in the '80s on specification and implementations of the Coloured Book Protocols. The development of gateways between OSI networks, EARN, DECNET and IP ones similarly required large-scale developments – at many different levels. They then required large-scale testing with real traffic. Indeed, I had research contracts from DARPA for some of these activities; the total legal justification (from the US viewpoint) for running the network services between Arpanet and the UK networks between 1973 and 1988 was the need to test these developments with real traffic.

The US always made a fairly sharp separation between academic work in network research and provision of network facilities. Until recently, most of the first was supported by DARPA and the second by NSF. This is the reason that DARPA was happy to support SATNET, Packet Radio Net and the Internet in its early stages – but then to withdraw from these in favour of NSF. DARPA continued to provide smaller test networks [[CAIRN](#)]; DARTNET, CAIRN, the Gigabit Network project [[GIGABIT](#)] and more recent optical networks as part of its research programme, but not to provide for large-scale use. This is the remit of NSF, who commissioned NSFNET, which was then transitioned into the private sector. A dilemma then often exists that some researchers need higher performance facilities than are normally provided. This is the reason that in the US Internet-2 [[Internet2](#)] has been provided. Internet-2 allows higher-speed applications to run than are supported on the normal commercial Internet. Moreover, it also allows experimental deployment of IPv6, Quality of Service, Multicast and many other important functions. It is no coincidence that much of the fundamental work on these technologies were first done on DARPA-sponsored test networks such as CAIRN.

The European scene has been substantially different. Much of the academic R&D has been done nationally, under various research funding sources. There has then been a substantial deployment – again nationally. The British have followed this track [[JANET](#)] with their Grid activities, for example, where there have been substantial activity in QoS and Access Grid work. The French have provided a pilot service early on their Renater [[RENATER](#)]. The Dutch have done some of the leading work in the provision of high speed facilities, optical networking and high-speed access to student housing [[SURFNET](#)]. Many of these initiatives are described in the different Terena Networking Conferences, including the present one.

The development environment is often good. In these circumstances, for all the higher level activities which do not require interfering with normal service network functions. Thus in the UK, for example, many development functions like conferencing, distance education and high-speed access go well. For experiments in QoS, there is a separate small (4-node) network. However, very few places can access this network, so that experimentation is difficult. For the IPv6 work, there are two problems: first, because the early routers had performance problems with IPv6, it has taken a long time before dual-stack has been supported in the service network; second, because the access networks are regional ones under different control, it has not necessarily proved possible to provide either QoS or IPv6 to end users.

The EC-funded activities have followed a similar track to the National ones. Under the earlier programmes, many of the developments under the ESPRIT projects were to develop network components and applications. Many networking developments (including the JAMES network) were done under the RACE programme. Many of the attempted deployments were done under the Telematics programme. A typical cycle was our experience with Directory and security services. Under an early EC ESPRIT project, we developed a first X.500 directory pilot product and an X.400 mail one in 1984-86. Under British national funding, this was developed further, and deployed on

JANET – with links to the US Internet during 1989-91. Then under COSINE auspices, we co-ordinated a pilot X.500 deployment [[PARADISE](#)] and a security one [[PASSWORD](#)]. Similarly under the Telematics initiatives, the EC supported activities for many years in piloting multimedia conferencing (MICE/MERCI/MECCANO) [[MECC](#)].

In the last few years, the EC has greatly strengthened their activities in supporting networking. We have already mentioned their significant support for GEANT as a research network. They have also insisted that GEANT incorporate IPv6, multicast and QoS as soon as possible. In addition, they have funded a substantial number of projects, under the same research networks action line, into development and exploitation of IPv6, wireless access, and other novel access techniques. For example the IPv6 deployment under 6NET [[6NET](#)] required initially a 155 Mbps network with terminations in some 34 sites. It was supposed to include terminations at up to 2.5Gbps; this is only now not going to be deployed because GEANT has deployed IPv6 dual stack on its backbone.

With the latest Framework 6 initiative, there is now a substantial difference in the way research and services in networks are treated. There are numerous initiatives that involve development of technology, followed by limited deployment. Some of these involve large-scale involvement of NRENs with limited, but vital, participation by commercial entities. Others follow the more normal path of fully mixed commercial and research institutions.

With the recent glut of optical fibre, there has been a welcome donation of high capacity links to the research community. Examples are the donation for 10Gbps research links between the US and Europe, and between the US and Australasia from the Internet Equal Access Foundation [[IEAAF](#)], and the planned GLORIAD links between the US, China and Russia [[GLORIAD](#)].

7 Conclusions

The technical progress over the last two decades is amazing. Twenty years ago the few NRENs that existed had even a National link speed of only 64 Kbps; now it is often 10 Gbps; this reflects a growth of 150,000 in 20 years – nearly 100% p.a. throughout the 20 years. Even internationally, where in most cases it was only 9.6 Kbps 20 years ago, it has reached 10 Gbps in the major regions. Even to less developed areas, speeds of 34 Mbps are the norm.

The first decade brought large-scale backbones up to low Mbps, resolved the protocol wars, made remote communication standard and gave web access. Advanced islands had real-time services with gigabit communications. The second decade brought backbones to low Gbps, remote access to Mbps, and readily available, real-time communications. Many remoter regions had the facilities of the previous decade in more advanced regions.

I indicate in Figs 1 and 2 where the European Service networks and the world-wide optical networks have reached to date. Here it should be noted that most of the networks of Fig. 1 are even IPv6 enabled. The optical networks of Fig. 2, which should be considered for the moment as networks for research, are equally impressive.

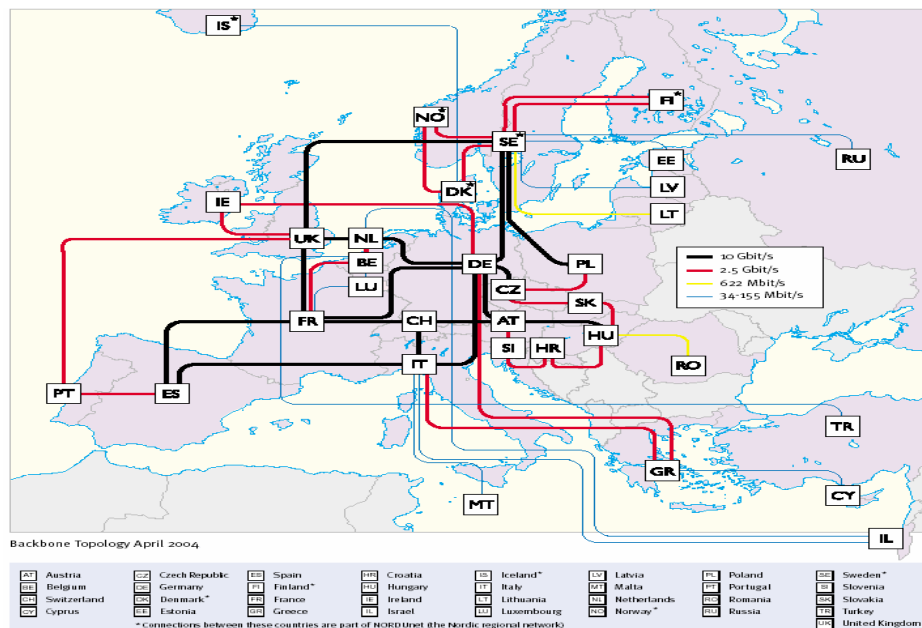


Figure 1 Schematic of GEANT, April 2004

It is not only the speed and extent of these networks which are impressive, it is the enthusiasm with which they are provided to the Research community by the funding bodies. In 1984, we had to fight hard to justify the maintenance of 64 Kbps international links; it 2004, networks like those of Fig. 1 are provided for services, and those of Fig. 2 to investigate high speed applications.

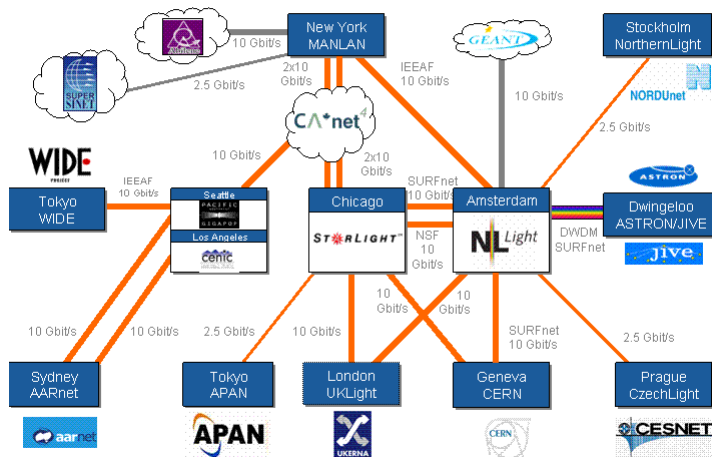


Figure 2 The status of Global Optical Network connectivity for research

The advent of these new networks should revolutionise many aspects of research and education. In particular, there should be little problem in carrying out global collaborative research, high-speed computing and distance education. The truly convenient applications environments are not yet there; that is our next challenge.

There are still constraints. Natural differences in data collections are not yet utilised fully; person-person real-time services over the Internet are lightly used so far; there is little widespread use of mobile access techniques. Security services are still in their infancy. There is inadequate application support. We do not yet have a realistic charging and payment base to create a market in areas like distance education and

telemedicine. There is not really a readiness to rely on remote computation; Central computing has been of limited use. There is still a lack of distributed, easily usable, grid computing, and there are severe service limitations from security considerations. In addition there are International barriers such as language and time of day differences, Intellectual Property considerations, nationalistic concerns of growth, pride and even censorship.

The keynote for TNC2014 will be very different. Electronic diffusion to the whole academic community should be a matter of course. But we can expect TNC 2014 to be needed still.

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